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Vol. V FEBRUARY, 1918 No. 2

BOSTON SOCIETY OF CIVIL ENGINEERS
FOUNDED 1848

PROCEEDINGS

NOTICE OF REGULAR MEETING.

A REGULAR meeting of the Boston Society of Civil Engineers will be held on

WEDNESDAY, FEBRUARY 20, 1918,

at 7.45 o'clock P.M., in CHIPMAN HALL, TREMONT TEMPLE, BOSTON.

Mr. Thomas C. Atwood will give an address on "The Submarine Menace and the Squantum Destroyer Plant." The address will be illustrated with lantern slides.

S. E. TINKHAM, *Secretary.*

NOTICE OF SPECIAL MEETING.

A special meeting of the Society will be held in the Society Rooms, 715 Tremont Temple, Boston, on Wednesday, February 27, at 7.30 o'clock P.M. Mr. Clayton W. Mayers, of the Aberthaw Construction Company, will read a paper entitled, "Economy in the Design of Concrete Buildings."

S. E. TINKHAM, *Secretary.*

SANITARY SECTION.

NOTICE OF ANNUAL MEETING.

The annual meeting of the Sanitary Section will be held in the Society Library, Tremont Temple,

WEDNESDAY EVENING, MARCH 6, 1918.

Mr. Charles H. Parker, Superintendent Generating Department, Edison Electric Illuminating Company, of Boston, will read a paper entitled, "Economy in the Use of Fuel in Power Stations."

PAPERS IN THIS NUMBER.

"Economy in the Design of Concrete Buildings." C. W. Mayers.

"Sewer Pipe Joints." Topical discussion.

Current Discussions.

Paper.	Author.	Published.	Discussion Closes.
"Foundations of the New Buildings of the Massachusetts Institute of Technology."	C. T. Main and H. E. Sawtell.	Jan.	Mar. 10
"Concrete Materials and Design of the New Buildings of the Massachusetts Institute of Technology."	S. E. Thompson.	Jan.	Mar. 10

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Contributors are hereby notified that proof will not be submitted to them for examination unless requested before the 10th of the month preceding the month of publication.

MINUTES OF MEETINGS.

Boston, January 23, 1918. — A regular meeting of the Boston Society of Civil Engineers was held this evening at Chipman Hall, Tremont Temple, and was called to order by the President, George C. Whipple, at 8 o'clock.

There were 40 members and visitors present.

The records of the last regular meeting and the special meeting of January 11, 1918, were read and approved.

The Secretary reported for the Board of Government the election of the following to membership: In the grade of member, Messrs. Clarance Lester Foster and Pusey Jones, and in the grade of junior Mr. Laurence Arnold Gillett.

The President presented, for the Board of Government, its recommendation that the following vote be passed: *Voted*, that a sum not exceeding one hundred and twenty-five dollars be transferred from the income of the Permanent Fund to the Current Fund, to cover the amount of unpaid dues for the present year of members who are in the war service of the country, and which have been remitted by the Board of Government under authority of the by-laws.

On motion of Mr. White, the recommendation was adopted by a unanimous vote.

The Secretary read a memoir of Otis F. Clapp, late a member of the Society, prepared by a committee consisting of William D. Bullock and Irving S. Wood. The memoir was accepted and ordered printed in the JOURNAL.

The President announced the death of Chauncey D. Bryant, a junior member of the Society, and of the 101st Engineers, which occurred in France on January 5, 1918. The President called attention to the fact that Mr. Bryant was the first member of the Society who had died in the present war service. By vote the President was requested to appoint a committee to prepare a memoir. He has named, as that committee, Mr. Robert Spurr Weston.

On motion of Mr. Eddy, the President was requested to appoint a committee of three to submit to the meeting the names of five members to serve as the committee to Nominate Officers for the Ensuing Year. The President appointed Harrison P. Eddy, Hartley L. White and Frank L. Fuller. Later in the meeting this committee presented the names of Frank A. Barbour, Robert Spurr Weston, George H. Brazer, David A. Ambrose and Dana M. Wood, and by vote they were duly elected as the Nominating Committee.

The paper of the evening was by Mr. Frank B. Walker, entitled, "Engineering Features in Connection with Loading and Hauling Iron Ore from Mesabi Range to Lake Docks." The paper was illustrated with lantern slides, and a number of specimens of the ore were exhibited.

Past President Eddy presided during the latter portion of the meeting, President Whipple having been obliged to leave on account of another engagement.

At 9.45 the meeting adjourned.

S. E. Tinkham, *Secretary*.

Boston, January 2, 1918.—A meeting of the Sanitary Section of the Boston Society of Civil Engineers was held this evening in the Society Library, Tremont Temple. The meeting was called to order at eight o'clock by the chairman, Mr. Frank A. Marston. The minutes of the December meeting were read and approved.

The subject discussed was sewer pipe joints, and the first speaker, Mr. J. Leslie Woodfall, read a very interesting paper relating his experience with various materials in different parts of New England. Mr. E. H. Rogers, city engineer of Newton, gave a detailed account of the method used in that city. Mr. H. A. Varney, town engineer of Brookline, described the various methods which had been used in that town. Mr. Hastings, city engineer of Cambridge, showed a method invented by him, of pouring a cement grout joint. He also described the method used in that city for constructing sewers and drains in wet ground, and showed a diagram of a concrete drain and the method of construction. Mr. Brewer, city engineer of Waltham, related his experience in sulphur and sand joints and several other materials. Mr. Carpenter and Mr. Branch also spoke on the subject. Mr. Neuff, of Adams, described a new method of pipe jointing in which metal gaskets were used instead of the ordinary rope yard.

Eighteen members and visitors were present.

The meeting adjourned at 10.15.

Henry A. Varney, *Acting Clerk*.

BINDING SOCIETY JOURNAL.

The Secretary has made arrangements for binding Volume 4 of the JOURNAL of the Society. The ten numbers will be bound in one volume, the style of binding to be uniform with that of previous volumes. The price of binding this year will be 90 cents per volume.

Numbers for binding must be sent to 715 Tremont Temple, Boston, before March 1, 1918. After this date, numbers will not be accepted for binding except with the understanding that they cannot be bound at the price named.

APPLICATIONS FOR MEMBERSHIP.

[February 12, 1918.]

THE By-Laws provide that the Board of Government shall consider applications for membership with reference to the eligibility of each candidate for admission, and shall determine the proper grade of membership to which he is entitled.

The Board must depend largely upon the members of the Society for the information which will enable it to arrive at a just conclusion. Every member is therefore urged to communicate promptly any facts in relation to the personal character or professional reputation and experience of the candidates which will assist the Board in its consideration. Communications relating to applicants are considered by the Board as strictly confidential.

The fact that applicants give the names of certain members as reference does not necessarily mean that such members endorse the candidate.

The Board of Government will not consider applications until the expiration of twenty (20) days from the date given.

KERSTEIN, BENJAMIN HOFFMAN, Dorchester, Mass. (Age 24, b. Boston, Mass.) Graduate of Mass. Inst. of Technology, 1916, civil engineering course, degree of S.B. From 1916 to date, resident engineer with Mass. Highway Com. Refers to A. B. Appleton, Alexander Bresth, R. W. Coburn, H. J. Hughes, J. H. O'Connor, and W. N. Wade.

Moore, Rufus Read, Boston, Mass. (Age 32, b. Milton, Ind.) Graduate of Boston three years' evening course in practical electricity, 1909, and of Northeastern College evening course in electrical engineering, 1916. From October, 1906, to June, 1909, with Lundin Electric and Machine Co., Boston, on repairs and construction work in central and sub-stations; from June to November, 1909, journeyman electrician with M. B. Foster Electric Co.; from November, 1909, to December, 1913, in other than engineering work; from December, 1913, to June, 1914, in charge of all electrical work for Phillips Electric Light & Power Co., Phillips, Me.; from September, 1914, to March, 1915, with various contractors in Portland, Me.; from March to September, 1915, engaged in electrical work on coast defenses of Portland, Me., and New London, Conn., districts; from September, 1915, to August, 1916, with Lundin Electric and Machine Co.; from August, 1916, to November, 1917, chief electrician of maintenance with Gray & Davis, Inc., Cambridge; is now draftsman with Harry M. Hope Engrg. Co., Boston. Refers to W. W. Clifford and C. M. Durgin.

Wansker, Harry A., Boston, Mass. (Age 24, b. New York, N. Y.) Student at Mass. Inst. of Technology, 1913 to 1915; graduate of Rhode Island State College, 1917, civil engineering course, degree of B.S. During summers of 1913, 1914, 1915 and 1916, and from May to November, 1917, with Darrow Mann Co., Charlestown, Mass., and Providence, R. I., on mechanical drafting, surveying, power plant construction and designing electrical apparatus for their large coal-handling plant; from November, 1917, to date, ship draftsman with Hull Division, Boston Navy Yard. Refers to F. A. Caldwell, T. G. Hazard, Jr., Willard Kent and L. E. Moore.

LIST OF MEMBERS.

ADDITIONS.

Allen, Elmer F. ....7 Highland Ave., Stoneham, Mass.
Bunker, Page S.,
Capt., Ordnance Dept., U. S. R., Augusta Arsenal, Augusta, Ga.
Foster, Clarance L. ....32 Central Rd. Somerville, Mass.
Gillett, Laurence A. ....92 Bromfield St., Newburyport, Mass.
Ullian, Hyman B. ....35 Creston St., Dorchester, Mass.
Wells, Edward P.,
Cadet, U. S. A. School of Military Aeronautics, Ithaca, N. Y.

CHANGES OF ADDRESS.

Adams, Edward P. ....1102 Exchange Bldg., Boston, Mass.
Appleton, Arthur B. ....11 Sherman St., Beverly, Mass.
Beard, Cornelius,
1st. Lieut., A Co., 101st Reg., U.S. Engrs., American Expeditionary Force, France
Brown, Albert F. ...36 Maxwell St., Dorchester Center Sta., Boston, Mass.

Craib, Charles G.....................375 Querbes Ave., Outremont, P. Q.
Craigue, Joseph S., Capt., D. G. T., American Expeditionary Force, France
Dolliver, Henry F.....................41 Salcombe St., Dorchester, Mass.
Green, Howard W...............................Box 364, Ancon, C. Z.
Harty, John J., Jr., care Monks & Johnson, 78 Devonshire St., Boston, Mass.
Hobson, George F........Capt., U. S. R., 305th Engrs., Camp Lee, Virginia
Johnson, Frank W.,
Raymond Concrete Pile Co., 2006 Finance Bldg., Philadelphia, Pa.
Luther, Howard B.,
Lieut. (Jun. Grade), U. S. N. R. F., 1707 H St., N. W., Washington, D. C.
Pierce, Charles H...........1st Lieut., E. R. O. T. C., Camp Lee, Virginia
Pratt, R. Winthrop...................2847 Broxton Rd., Cleveland, Ohio
Reed, Leslie P.,
2d Lieut., U. S. Signal Reserve Corps, Engrg. Section,
Room 356, Union Sta., Washington, D. C.
Wade, Clifford L.,
1st Lieut., Engrs., U. S. A., care U. S. Geological Survey, Washington, D. C.
Webb, George F..........................P. O. Box 861, Bellows Falls, Vt.
Wood, Carl W...........................39 Greenleaf St., Malden, Mass.
Wood, Frederic J.,
Major, Engineers, U. S. R., Curtis Bay Ordnance Depot, So. Baltimore, Md.
Worcester, Robert J. H.,
1st Lieut., Inf. R. C., 12th Co., 3d Battalion, Depot Brigade,
Camp Devens, Mass.
Young, Erving M.,
care Constructing Quartermaster, Curtis Bay Ordnance Dept., Md.

DEATH.

Bryant, Chauncey Davis, 101st Engineers, American Expeditionary Force.
Died in France, January 5, 1918.

EMPLOYMENT BUREAU.

The Board of Government maintains an employment bureau for the Society, to be a medium for securing positions for its members and applicants for membership, and also for furnishing employees to members and others desiring men capable of filling responsible positions.

At the Society room two lists are kept on file, one of *positions available* and the other of *men available*, giving in each case detailed information in relation thereto.

MEN AVAILABLE.

417. Graduate of University of Maine, civil engineering course. Has had several years' experience in responsible charge of general building construction, as superintendent and engineer. Is above draft age, and American citizen. Will give Boston interview and references to persons interested.

LIBRARY NOTES.

RECENT ADDITIONS TO THE LIBRARY.

U. S. Government Reports.

Annual Report of Chief of Weather Bureau for 1916–17.

Annual Report of Superintendent, United States Coast and Geodetic Survey, for 1916–17.

Potash in 1916. Hoyt S. Gale.

Pottery in 1916. Jefferson Middleton.

Salt, Bromine and Calcium Chloride in 1916. Ralph W. Stone.

Spirit Leveling in Mississippi, 1901 to 1915, inclusive. R. B. Marshall.

Spirit Leveling in South Dakota, 1896 to 1915, inclusive. R. B. Marshall.

Strontium in 1916. James M. Hill.

Thorium Minerals in 1916. Waldemar T. Schaller.

United States Magnetic Tables and Magnetic Charts for 1915. Daniel L. Hazard.

State Reports.

New Jersey. Quaternary Formations of Southern New Jersey. Rollin D. Salisbury and George N. Knapp.

New York. Annual Reports of Conservation Commission, Division of Inland Waters, for years 1911 to 1914.

New York. Annual Report of State Department of Health for 1915.

Municipal Reports.

Boston, Mass. Annual Report of Public Works Department for 1916.

Detroit, Mich. Annual Report of Department of Parks and Boulevards for 1916–17.

New York, N. Y. Report of Board of Water Supply on Completion of First Stage of Catskill Water Supply System, 1917.

Philadelphia, Pa. Annual Report of Bureau of Surveys for 1916.

Miscellaneous.

Canada, Department of Mines. Radioactivity of Some Canadian Mineral Springs. John Satterly and R. T. Elworthy.

Contribution of Society of Portuguese Civil Engineers to World's Columbian Exposition, 1893. Gift of Massachusetts Institute of Technology Library.

Hydrated Lime Bureau. Watertight Concrete.

Institution of Civil Engineers (London). Minutes of Proceedings, Vol. CCIII, 1916–17.

Street Railway Fares. Dugald C. Jackson and David J. McGrath. Gift of Massachusetts Institute of Technology.

Sydney University Engineers: Their School and Their Work. James Vicars.

The War, Australia and the Engineer. S. H. E. Barraclough.

LIBRARY COMMITTEE.

NEW ENGINEERING WORK.

(Under this head a brief description of new engineering work contemplated or under construction will be presented each month. Engineers and contractors are requested to send descriptions of their work to the Secretary, 715 Tremont Temple, Boston, before 1st of each month.)

Commonwealth of Massachusetts.— METROPOLITAN WATER AND SEWERAGE BOARD. — *Water Works.* — All of the poles and towers for the transmission line between the Wachusett and Sudbury power stations have been erected, and some of the cross arms have been placed.

At the Arlington pumping station the new three-million-gallon centrifugal pumping unit has been received, and is now being erected.

METROPOLITAN WATER AND SEWERAGE BOARD. — *Sewerage Works.* — Work in progress: Section 98, Wellesley Extension.

METROPOLITAN PARK COMMISSION. — *Old Colony Parkway.* — Construction of a temporary bridge across the Neponset River between Boston and Quincy is in progress; also construction of double siphon for water and gas under new channel.

BOSTON TRANSIT COMMISSION. — *Dorchester Tunnel.*— Work is progressing on the interior finish of the station at Andrew Sq., and work is in progress on the station for transfer of passengers from the surface cars to the tunnel below.

New York, New Haven & Hartford R. R. Co.—*South Boston Cut Improvement.* — Enlargement of South Boston Cut to Boston Freight Terminal, to accommodate four tracks instead of two, and reconstruction of eleven overhead highway bridges, so as to span four tracks instead of two, progressing. Excavation by steam shovel has advanced from westerly end of cut through West Fourth St. Bridge abutments being constructed at West Sixth St. and West Fifth St.

Vol. V FEBRUARY, 1918 No. 2

BOSTON SOCIETY OF CIVIL ENGINEERS
FOUNDED 1848

PAPERS AND DISCUSSIONS

This Society is not responsible for any statement made or opinion expressed in its publications

ECONOMY IN THE DESIGN OF CONCRETE BUILDINGS.

By Clayton W. Mayers.*

(To be presented February 27, 1918.)

Part I.

Hidden Wastes.

Upon the designing engineer of concrete buildings rests the big responsibility of conservation of building materials. The mere fact that concrete is composed of cement, sand and stone, of which there seems to be an excellent supply, does not in any way relieve the designer of concrete construction of the obligation of careful study of the work in hand in order that no excess of material be used. Most errors made in concrete design are not easily recognized even by experienced estimators of building construction. Hidden away inside a column there may be reinforcing steel which should be elsewhere doing work at less expense to the owner, as would have been the case had the designing engineer given proper thought to the design of this column. A large percentage of the floor space occupied by columns might be storage space for the same reason. The beams may contain an excess of steel reinforcement simply because it was less trouble to call for straight top rods to take care of negative bending than it was to determine where and how bends could have been made in order to have used the least amount of reinforcement in the design. Flat slabs may have a number of individual rods over the top of each column head, where a few more bottom rods should have been bent up to take care of this negative bending. And yet this entire building may have been designed in accordance with the recognized standards of concrete design. These errors are not errors in computations, but are errors of careless design, and the result is dire waste of material.

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* With the Abertaw Construction Company, 27 School Street, Boston, Mass.

Note. This paper is published in advance of its presentation before the Society. Discussion is invited, to be received by the editor before April 10, 1918, for publication in a subsequent number of the Journal.

Study for Economy a Necessity.

In most cities, building plans are OK'd by responsible engineers authorized by the city to pass upon these plans before the work is allowed to proceed. Errors in computation are usually detected in this process, but who ever heard of one of these authorized engineers returning a set of plans with suggestions for a more economical design? Provided the building is strong enough, the design is approved. It is not the function of city building departments or their engineers to look for economies or suggest savings.

Hence, if the designing engineer does not study economy in the design of his work, he may be reasonably sure it will get very little such study from any one. Designs prepared without this special study are sure to show a waste of building material, and the building is no better, and serves no better purpose, because of this extra expense.

Recognized standards are observed by most designers of concrete buildings as regards stresses and strains, factors of safety, etc., but unfortunately no rules, tables, or data are at hand which will solve the problem of maximum economy in the choice of the various methods of concrete construction which may be used. Each building presents new problems. It is a case of careful study in an intelligent way, and the designer must do this work well if he would " do his bit " and at the same time keep or build up his reputation.

Is there any position more humiliating to the designing engineer of a contemplated structure than to have other parties submit to the prospective owners a more economical design based on the same fiber stresses as were used in the original layout? This is not an uncommon event, and uncomfortable complications always arise.

A general survey of conditions and inspection of the possible methods of construction usually constitute the first thought given to a new problem of structural design. By this inspection a process of elimination is set up, and finally the engineer considers only a few schemes which could be well employed to give the owner a structure suitable for his purposes. The next step usually consists of viewing the several schemes from every angle in order to study their individual merits. Each layout possesses different advantages, some of more value than others, but each one would answer the purpose very well. For instance, a beam and girder type of floor construction may offer advantages in the way of hanging shafting if the building is to be used for certain types of manufacturing. Column spacing would perhaps work out to better advantage in one scheme than in another. Thus the discussion continues, with here and there a remark about the probable cost of this and that. A decision is usually made in favor of the scheme offering the most advantages even though they are trivial. The plans are drawn up on this basis, and the work proceeds. The detailed design is finished with about the same attention to costs as has been given to the selection of the type of construction used. Generally, the owner of the completed building is satisfied, and, if he could have had just as good a building for less money, he never knows it.

Comparative Cost Estimating.

The average concrete designer makes no claim to being an estimator. In fact, he does not think it is necessary to be an estimator even of the materials with which he works. It is a fact that a large majority of men employed in the design of concrete buildings have hardly any idea of the cost of the work they are laying out, and what is more, they do not know how to find this out for themselves. Surely, if an engineer designed a structural steel girder he could tell with reasonable accuracy what it would cost by computing the weight and getting the market price of the structural steel and the labor cost of erection. Estimating the cost of concrete work is a little more complex, but each step is very similar and the process is the same.

A designer of concrete structures should think continually of costs. In order to think intelligently of the cost of his work he must know how to calculate approximately the cost of his designs. In no other way is he able to determine which one of his studies will serve his purpose at the least expense.

It should be borne in mind that in making designs for comparative costs, it is not necessary to work to as great a degree of accuracy as for the finished plans. Rough designs, accompanied by rough sketches, will furnish enough information for this study. In case the comparative costs of two schemes should work out the same, a more careful design might become necessary. A little practice on the part of the designer will soon reveal to him to what degree of accuracy he must work in order to get satisfactory results.

Accuracy of Unit Costs.

The process of estimating these various designs for comparative cost purposes is not nearly as difficult as may be supposed. Concrete is measured by the cubic foot or cubic yard, forms by the surface measurement in square feet, and reinforcement by the pound or ton. After the quantities have been calculated for the various designs, unit prices are fixed and the total cost of the member estimated. It is usually here that the engineer throws up his hands. In fact, it is very likely that he knows but little about the prices of this class of material and labor, and in his rush of work he has not kept in touch with their fluctuations, and feels he does not have time to inform himself properly on this subject. Again, it should be understood that it is not necessary to fix absolutely accurate unit costs to these quantities in order to obtain reasonably accurate cost comparisons. As long as the same unit costs are used for similar types of work in the various designs, the comparative costs will be surprisingly accurate. In fact, some of the unit costs may be in error 25 per cent. or 30 per cent., and yet the resulting costs will show unquestionably which type of construction should be used. However, the alert engineer will soon become as interested in having his unit costs in accordance with current prices of material and labor as he is in having his design correct.

Effects of Design on Costs.

Contrary to the opinion of most engineers, the concrete building design calling for the least amount of material is not always the cheapest building to erect, as such a building may call for much more labor. Form work is a big factor in the cost of concrete buildings, and this phase of the operation must be given careful consideration in order to simplify the construction of the form work as much as possible. Study must be made also to determine whether the complexity of forms in a comparatively light design would not make the final cost of the building in excess of a building designed of simpler yet heavier construction. Concrete floors designed on the flat slab method sometimes have considerably more material in them and yet work out cheaper than a beam and girder type designed for the same conditions. Placing reinforcement costs more per ton and forms more per square foot in a beam and girder construction than the same operations in a flat slab construction. In laying out floors of the beam and girder type, the addition or omission of one beam per bay may influence the cost of the design a great deal. Changes in column spacings will also have the same effect. It is only by making the design of a typical floor bay of the various schemes considered and getting the quantities and costs of these schemes that it will be possible to tell definitely which method should be used. Many times concrete columns should be composed of a richer mix of concrete and have less reinforcement. In a building of several stories it is necessary to devote considerable study to the design of columns in order to locate the point where the mixes should change, where spirally reinforced columns should be introduced, and also to consider carefully the loss or gain of floor space occupied by columns. It will be necessary to make several sketch designs and calculate the cost of each. Thousands of dollars may be wasted by improper column design and still the error is one which would not readily attract attention. There is a certain type of design for every part of the construction which will show maximum economy, and it is up to the designing engineer to calculate the costs of his various designs and determine for himself which one should be used.

Unit Costs for Comparative Estimates.

Up to this point this article has emphasized, principally, the necessity of making several preliminary designs of the various members of a concrete building and calculating the cost of each design before the final layout is begun. Not much light has been shed upon the method of obtaining unit prices to fix to the quantities of material and labor. Unit prices are subject to wide fluctuations. Markets, labor, location of the work in question, speed of the operations, etc., and many other items enter into the making of these costs. However, as stated before, these unit prices need not of necessity be extremely accurate, and the designing engineer need not feel that he cannot price closely enough to obtain fairly accurate results.

A list of approximate unit prices have been tabulated here which may be used to calculate the comparative costs of the principal members in a concrete building. Judicious use of these unit costs will enable the designer to incorporate in his design the most economical methods and at the same time develop a keener eye for economical construction.

Concrete.

Concrete (1 : 2 : 4 mix), per cu. yd.	Cement, $1\frac{2}{3}$ bbls. at $2 per bbl. at the job			$3.33
	Sand, $\frac{1}{2}$ cu. yd. at $1.50 per cu. yd. at the job			.75
	Crushed stone, $1\frac{3}{10}$ tons at $2 per ton at the job			2.60
	Plant, cost per cu. yd.	Freight charges	$0.05	
		Rental of mixer, etc.	.35	
		Purchases (small tools, fuel and supplies)	.45	
		Labor	.40	
				1.25
	Labor of mixing and placing			1.25
Total cost per cu. yd.				$9.18
Total cost per cu. ft.				.34

Concrete mixed in the proportion of 1 : 1½ : 3 will require about one third of a barrel more cement per cubic yard. This will add about 67 cents to the cost of one yard of concrete in place, making the unit price about $9.85 per cubic yard, or 36½ cents per cubic foot. If a 1 : 1 : 2 mix of concrete is used, the cement will be increased about $1\frac{2}{10}$ bbl. over and above that used in a 1 : 2 : 4 mix. At $2 per bbl. this would make the cost of 1 : 1 : 2 mix concrete about $11.58 per cu. yd., or 43 cents per cu. ft. In large, plain concrete footings it is sometimes advisable to use a concrete mixed in the proportion of 1 : 2½ : 5. Concrete mixed in this proportion requires about three tenths of a barrel less cement than 1 : 2 : 4 mix. Figuring cement at $2 per bbl., concrete mixed in the proportion of 1 : 2½ : 5 works out at approximately 32 cents per cu. ft. in place.

In calculating the amount of materials necessary to make 1 cu. yd. of concrete, it will be noticed that the only change made in the quantities for the various mixes has been in the amount of cement used. It has been assumed that a cubic yard of 1 : 1 : 2 concrete will require the same quantity of sand and crushed stone as a cubic yard of 1 : 2 : 4 concrete. Theoretically this is not true, but in general practice there is some waste of material and it has been found that the small differences of aggregate used in the various mixes of concrete in a building are negligible. A very large part of the concrete in a building is a 1:2:4 concrete, therefore the aggregate quantities of 1:2:4 mix are generally used for all concrete work, and the cement alone is changed for various mixes. It will also be noted that the quantity of cement, sand and stone used here is somewhat in excess of the amount usually given in the tables published in various text-books. It must be borne in mind that the waste of materials on the job must be absorbed, and the quantities in tables compiled by laboratory tests must be somewhat increased. It is actually necessary to estimate on about 1⅔ bbl. of cement to make 1 cu. yd. of 1:2 : 4 concrete on a job where the usual construction methods are employed, and in other mixes of concrete the cement should be proportionately increased.

The prices of concrete work as tabulated here are about 30 per cent. in excess of pre-war prices and 50 per cent. more than the prices of 1913. These costs based on the present high cost of material and labor should be adjusted from time to time as necessary.

"Plant."

In making estimates for the cost of concrete in place, the most uncertain element entering into this cost is the item of "plant." The cost of "plant and tools" varies greatly with different contractors, and depends largely upon the foresight of the persons responsible for the layout of the job operations. The number and location of the mixers, towers and runs used on the job, layout and extent of storage space for aggregate, source and expense of power, etc., distance over which concrete machinery has to be transported, good or bad mechanical conditions of rented machinery, rental rates of machinery, replacement of missing shovels and other tools, and many other variable expenses go to make up this cost. The size and shape of the building, as well as the speed of the operations, play an important part in this cost. The "plant" cost for a job containing 6 000 cu. yds. of concrete need not necessarily be one-fifth more than a job containing 5 000 cu. yds. of concrete. The "plant" will, of course, cost more for the job containing 6 000 cu. yds. of concrete, but since the cost of erecting and dismantling the "plant" work for both jobs may be the same, the extra cost of "plant" for the larger job will be principally extra depreciation or rental, fuel, power, wear and tear, and loss of tools. However, "plant" expense enters into all concrete costs, and must be included in the unite price of concrete if we would get a reasonably accurate idea of the ultimate cost of the work. At the present high cost of all building materials and labor, "plant" costs cannot be safely assumed to be less than $1 per cu. yd. and will very seldom run as high as $2 per cu. yd. of concrete. Owing to this wide variation in the cost of "plant," it is necessary in estimating concrete to strike an average cost which, while not accurate, will cover the usual "plant" work, and give a unit cost for concrete in which all items of material and labor have been considered. It is with this in view that a "plant" cost of $1.25 per cu. yd. has been used in making up the unit cost of concrete in place as given in the above tabulation.

Steel Reinforcement.

The cost of steel reinforcement is extremely erratic in its fluctuation, but at present it may be assumed at $90 per ton, exclusive of the labor of bending and placing. It will cost from $6 to $15 per ton to cut, bend and place this reinforcement, $100 per ton, or 5 cents per lb., being a unit price which may be used to give reasonably close cost ratios. Reinforcement requiring much bending and made up of small bars should be figured about one half cent per lb. higher than steel requiring only a small amount of bending. Spiral reinforcement for columns should be figured at an extra cost of about one-half cent per lb. over and above plain bars. In estimating the weight of spiral reinforcement it should be remembered that about 7 per cent. should be added to the weight of the spirals for welding laps. Also, it will be necessary to add about 3 lbs. per lin. ft. of column for spacers used to hold the spirals in proper pitch.

Forms.

Forms for round columns are usually made from sheet metal, and in flat slab construction it usually works out cheaper to use round interior columns formed with this material. However, the cost of forming an interior column 26 ins. in diameter for flat slab construction is about the same as forming a column 20 ins. in diameter designed for the same purpose. This being the case, it is not necessary to consider the difference in the cost of forms due to different diameters of round interior columns. It may be well to remember that it costs somewhat less to build an interior column having a head by using a steel form than it does to form the column of wood, as the cost of forming the head in wood is no small part of the column cost. The list of unit prices given here covers the cost of labor and material for form work for the principal operations in a concrete building, but are tabulated for use in making comparative estimates only. It must be borne in mind that these unit prices are for the use of the engineer in weeding out the more expensive designs, and are not to be used for making actual estimates of buildings without regard to conditions and what not. While these costs might be more or less useful in arriving at the total cost of a concrete building, it should be remembered that they are only approximate units to be used for the purpose outlined herein.

Type of Construction.	Sq. Ft. Cost. (Surface Measurement.)
Forms for flat slabs, including drop panels	$0.09
Slab, beam and girder construction, slabs to span not less than 9 ft.	.12
Slab, beam and girder construction, slabs to span not less than 7 ft.	.13
Slab, beam and girder construction, slabs to span not less than 5 ft.	.14
Column forms	.15
Floor beams and girders, not including slabs	.16
Wall beams	.14
Partitions and wall forms	.15
Footing and foundation forms	.15
Round steel column forms, including heads, each	15.00

Estimates Made from Cross-Sections.

Now that the methods of arriving at the comparative costs of the various types of concrete construction have been outlined, it is believed the designer will be able to work more intelligently regarding the cost his work involves. Typical dimensioned sketch cross-sections of the building from the roof slab to the footings should be made, and the work of estimating done from these sketches. In this way the extra column lengths required to obtain the same clearstory heights will enter into the estimate. This is quite a factor in comparing flat slab with beam and girder designs. Estimates made from these cross-sections for a length of building equal to one bay only, is the usual practice. In this way the cost per linear foot of building as well as the cost per square foot of floor space may be calculated. Comparisons of costs made in this manner are genuine proofs to the designer that he is giving the design proper study for economy, and will result in a conservation of building materials, save good dollars for the owner, and establish for the engineer the reputation of being a designer of economical concrete buildings.

PART II.

Columns.

Probably no part of a concrete building is simpler to design than the columns, and because of this simplicity the designer is very likely to give this part of his computations very little special study. It is also true that no part of a concrete building can conceal so effectively the lack of economical design as can the columns.

The economical design of the columns for a concrete building of only one or even two stories in height, is not a matter requiring much special study, but in buildings several stories in height the subject is one of vast importance. It is not possible to design columns showing maximum economy without careful consideration of several important facts. Engineers designing concrete buildings realize that a richer mix of concrete costs more than a leaner mix. They realize that to offset this extra cost of a richer mix of concrete in column design, there is a corresponding decrease in reinforcement which results in a change in the total costs of the concrete columns. The manipulation of these mixes of concrete in order to determine the most economical column construction is a subject for real study, and to accomplish this end the engineer will find it necessary to make several trial designs and calculate the cost of each design. For example, a column 26 ins. in diameter, composed of concrete mixed in the proportion of 1 : 1½ : 3, reinforced with eleven 1-in. round rods and 1 per cent. spiral hooping, will carry about the same load as a column of the same diameter composed of 1 : 1 : 2 concrete, reinforced with seven ⅞-in. round rods and 1 per cent. spiral hooping. As both of these are good designs, the question arises as to which one would be the most economical. Assuming the unit price of 1 : 1½.: 3 and 1 : 1 : 2 concrete at 36 cents and 43 cents per cu. ft. respectively, vertical reinforcement at 5 cents per lb., and spiral hooping at 5½ cents per lb. in place, it can be clearly shown that the column composed of 1 : 1 : 2 concrete will prove to be the more economical one to use. The point at which the column mixes change and where spirally reinforced columns should be used is determined only by making these comparative estimates.

It is not uncommon to see detailed plans calling for a lap in all the rods in a lower story column without regard to the fact that the column above may call for a lesser number of rods for its reinforcement, and it is only necessary to lap part of them. This is real waste, and shows careless design which will run into money faster than the designer suspects. For illustration, the first-story wall columns of a concrete building are 36 x 34 ins., reinforced with twenty 1⅛-in. round rods. The second-story wall columns are 36 x 30 ins., reinforced with fourteen 1⅛-in. round rods. A lap of thirty diameters is called for in all column rods. If the entire twenty rods in a first-story column are lapped into the second-story column it means that six of these twenty 1⅛-in. rods have been unnecessarily lapped and consequently this extra reinforcement wasted. Had only fourteen of these first-story column rods been lapped into the second-story column instead of twenty, a saving of about 17 lin. ft. of 1⅛ in. round steel rod would have been made. This reinforcement, figured at 5 cents per lb., would have shown a saving of about $3 at this one point. Multiply this saving by the number of columns in the building where such laps occur and it becomes no small item. The expense of a case of this kind becomes considerably greater when the column in question is a wall column on which is superimposed a so-called turned-up wall beam designed to be poured with the floor slab. In this case the specified lap begins at the top of the wall beam instead of the top of the floor slab and extends upward. For example, suppose a wall beam, extending 14 ins. above the second floor, designed to be poured with the slab, had been superimposed on the 36 x 34-in. wall column just discussed. In this case the lap must be measured from the point where pouring is stopped. If the twenty 1⅛-in. round rods are all carried up into the second-story column for a lap of 30 diameters it means that all the rods must extend to a point 4 ft. above the second floor, when in reality it is necessary to carry only fourteen of these rods to this point, starting the fourteen 1⅛-in. round rods in the second-story column at a point 14 ins. above the second floor and extending upward. The loss incurred by carrying the entire twenty 1⅛-in. round rods into the second-story column is about 24 ft. of 1⅛-in. round rod, which at 5 cents per lb. is about $4, as against the loss of $3 when no wall beam is designed to be poured with the floor slab. Wastes of this nature, at the present high price of reinforcement, are serious.

In the design of wall columns it will be necessary, usually, to consider the amount of sash and curtain wall required to fill the space between columns, as the smaller the width of the exterior columns the more sash and curtain wall will be required to fill in the space between these columns. This may seem trivial, but it will oftentimes give false impressions of economy if all these seemingly trivial details are not given a place in the estimated comparative costs of the various designs.

Illustrations of the methods of determining the economical interior column are given below. It may be well to add that no attempt is made to consider any of the various methods of concrete design from an engineering standpoint. This paper is not intended to be a text on design in any form, but rather it is intended to present to the designing engineer a method by which he can solve for himself the question of economy in his work. Hence, the reader should study the examples given here with a view of applying the methods of cost calculation to his work and not draw engineering conclusions from any of these illustrative costs.

Several comparative designs for any interior column (Fig. 1) are shown here. The comparative costs of the various schemes are worked out in detail, using unit prices principally from tabulations in Part I of this paper.

	Design.	Comparative Estimates.		
Scheme (a)	36-in. dia. col. 11 1⅛-in. rd. vert. rods ⅜-in. rd. bands 12 ins. o/c Mix 1 : 2 : 4	Conc. Forms. Reinfct. Lost floor space.	99 cu. ft. at 34c. Round steel. 716 lbs. at 5c. 5 sq. ft. at $2.75.	$33.66 15.00 35.80 13.75
		Total.		$98.21
Scheme (b)	32-in. dia. col. 23 1⅛-in. rd. vert. rods ⅜-in. rd. bands 12 ins. o/c Mix 1 : 2 : 4	Conc. Forms. Reinfct. Lost floor space.	79 cu. ft. at 34c. Round steel. 1 437 lbs. at 5c. 3⅒ sq. ft. at $2.75.	$26.86 15.00 71.85 8.53
		Total.		$122.24
Scheme (c)	2-in. dia. col. 12 1⅛-in. rd. vert. rods. ⅜-in. rd. bands 12 ins. o/c Mix 1 : 1½ : 3	Conc. Forms. Reinfct. Lost floor space.	79 cu. ft. at 36½c. Round steel. 770 lbs. at 5c. 3⅒ sq. ft. at $2.75.	$28.84 15.00 38.50 8.53
		Total.		$90.87

	Design.	Comparative Estimates.		
Scheme (d)	26-in. dia. col.	Conc.	52 cu. ft. at 36½c.	$18.98
	11 1-in. rd. vert. rods	Forms.	Round steel.	15.00
	1 per cent. spirals (18½ lbs.) per lin. ft.	Reinfct. (vert.)	514 lbs. at 5c	25.70
		Spirals.	264 lbs. at 5½c	14.52
	Mix 1 : 1½ : 3	Lost floor space.	$\frac{7}{10}$ sq. ft. at $2.75	1.92
		Total.		$76.12
Scheme (e)	28-in. dia. col.	Conc.	60½ cu. ft. at 43c.	$26.02
	20 1⅛-in. rd. vert. rods.	Forms.	Round steel.	15.00
	⅜-in. rd. bands 12 ins. o/c	Reinfct.	1 255 lbs. at 5c	62.75
	Mix 1 : 1 : 2	Lost floor space.	1.45 sq. ft. at $2.75	3.99
		Total.		$107.76
Scheme (f)	26-in. dia. col.	Conc.	52 cu. ft. at 43c.	$22.36
	7 ⅞-in. rd. vert. rods	Forms.	Round steel	15.00
	1 per cent spirals (18½ lbs.) per lin. ft.	Reinfct.	245 lbs. at 5c.	12.25
		Spirals.	264 lbs. at 5½c	14.52
	Mix 1 : 1 : 2	Lost floor space.	$\frac{7}{10}$ sq. ft. at $2.75	1.92
		Total.		$66.05
Scheme (g)	24-in. dia. col.	Conc.	44½ cu. ft. at 43c.	$19.14
	10 1⅛-in. rd. vert. rods	Forms.	Round steel.	15.00
	1 per cent. spirals (16 lbs.) per lin. ft.	Reinfct. (vert.)	606 lbs. at 5c	30.30
		Spirals.	229 lbs. at 5½c	12.60
	Mix 1 : 1 : 2			
		Total.		$77.04

From the above estimated comparative costs, perhaps the most noticeable fact is that the columns using the 1 : 2 : 4 mix of concrete are among the most expensive. Using this lean mix necessarily produces a column larger in diameter, which means, also, a loss of valuable floor space. It will also be noticed that the smallest column designed is not the most economical. The column which shows the most economy in this case is one having a 1 : 1 : 2 mix and about 1 per cent. of vertical reinforcement, together with 1 per cent. of spiral reinforcement. Hence, a rich mix of concrete and comparatively small percentages of steel reinforcement seem to show the most economical results for a column carrying a fairly heavy load.

For comparative purposes, the difference in the amount of concrete in the column heads may be neglected, as the top diameter of the head usually remains the same throughout the building. The cost of forming the column and its head has been estimated here at $15 each. This is done for convenience in arriving at a total cost of the column shaft. Ordinarily this cost is neglected in making comparative estimates of interior round columns, as it costs about the same to form a round column of small diameter as it does a column of larger diameter. Many other schemes may be designed for this particular column, and the comparative costs estimated. However, these several examples, some of which are obviously too expensive to consider, will suffice to give the reader a working knowledge of the methods of calculation employed to determine the costs of the various types of interior columns. It is readily appreciated that even though a larger column were somewhat cheaper to build, the additional floor space occupied by this larger column might be worth more to the owner of the building than he would save in the construction of the column. Hence, it becomes necessary to consider the value of this additional floor space as a part of the cost of this larger column. It is difficult to say just what this floor space is really worth. However, a satisfactory way to deal with the situation is to consider the smallest column designed as a basis to which the other columns are to be compared. In the above illustration this column is 24 ins. in diameter. Consider the area of floor space occupied by a column equal to the square of the diameter of the column. The additional area occupied by any one of these larger columns is equal to the difference of the square of the diameter of the column in question and the square of the diameter of the smallest column design. This additional or lost floor area is priced at a unit cost equal to the approximate unit cost per square foot of floor space of the completed building including heating, lighting, sprinklers, etc. The unit cost per square foot of building is calculated by dividing the approximate total cost of the building by the number of square feet of floor space in the building, measurements to be taken "out to out" of the floor plan. For example, a building 200 x 60 ft. and five stories high may cost $165 000 complete. This works out at $2.75 per sq. ft., and for general purposes this will give fairly accurate results for the purpose described above.

In the comparative estimates of the interior column (Fig. 1) given, if we strike out of each estimate the cost of lost floor space, the relative cost of each column will remain unchanged. This is not always the case, and even in our examples it will be noticed that the columns having the leaner mixes show up much more favorably when this item of cost is excluded from the total cost of the column. Frequently, the omission of this item will result in a transposition of the economic order of the various designs. In many buildings the loss of a few feet of floor space is immaterial, but in other cases it is of great importance, as in storehouses or in buildings where the machinery layout would be interfered with by a larger column. Where loft buildings or offices are rented by the square foot of net area the cost of this floor space should be figured at a considerably higher figure than the one given in our tables.

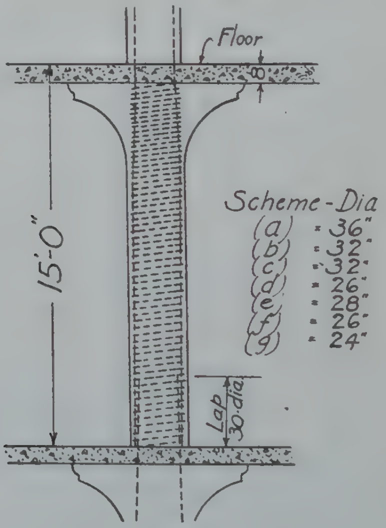


Fig. 1. Interior Column.

In determining the economical wall column, the method is very similar to that used for interior columns except that the item of the cost of wood forms enters into the estimate. It will be necessary also in designing exterior columns to consider the width carefully, as every inch added or deducted to the width of the column will change the corresponding dimension of wall sash a like amount.

Consideration is given below to the economical design of a typical wall column (Fig. 2) for a concrete building having these columns spaced 20 ft. on centers. For lack of space only three designs will be compared here, but the principles are clearly illustrated, and further designs should be treated in a like manner.

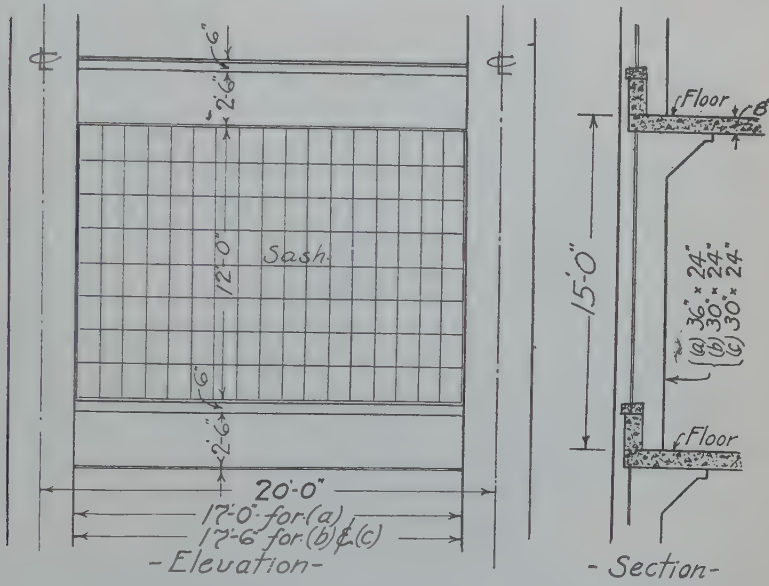


FIG. 2. TYPICAL WALL COLUMN.

Design.		Comparative Estimates.	
Scheme (a)	36 x 24 ins. 12 ⅛-in. rd. rods 17 ft. 6 ins. ⅜-in. rd. bands 12 ins. o/c	Conc. . . . . .86 cu. ft. at 34c.	$29.24
		Forms. . . . . .143 sq. ft. at 15c.	21.45
		Reinfct. . . . . .777 lbs. at 5c.	38.85
		Curtain walls. . . .31 sq. ft. at 75c.	23.25
		Window sill. . . . . .17 lin. ft. at 60c.	10.20
		Sash and glass. . .204 sq. ft. at 45c.	91.80
		Total.	$214.70
Scheme (b)	30 x 24 ins. 101 ⅛-in. rd. rods 17 ft. 10 ins. ⅜-in. bands 12 ins. o/c Mix 1 : 1½ : 3	Conc. . . . . .71⅔ cu. ft. at 36½c.	$26.16
		Forms. . . . . .129 sq. ft. at 15c.	19.35
		Reinfct. . . . . .651 lbs. at 5c	32.55
		Curtain walls. . . .32 sq. ft. at 75c.	24.00
		Window sills. . . . .17½ lin. ft. at 60c.	10.50
		Sash and glass. . .210 sq. ft. at 45c.	94.50
		Total.	$207.06

	Design.	Comparative Estimates.	
Scheme (c)	30 x 22 ins. 12 ⅞-in. rd. rods 17 ft. 2 ins. ⅜-in. rd. bands 12 ins. o/c Mix 1 : 1 : 2	Conc. 46 cu. ft. at 43c.	$19.78
		Forms. 124 sq. ft. at 15c.	18.60
		Reinfct. 460 lbs. at 5c	23.00
		Curtain wall. 32 sq. ft. at 75c.	24.00
		Window sills. 17½ lin. ft. at 60c.	10.50
		Sash and glass. 210 sq. ft. at 45c.	94.50
		Total.	$190.38

The cost of each wall column design includes the cost of sash and glass together with the curtain wall necessary to fill in one bay. For convenience in making these estimates, it is assumed the glass is factory ribbed glass costing 20 cents per sq. ft., including glazing. Steel sash is estimated here at 25 cents per sq. ft., erected and pointed, making a total of 45 cents per sq. ft. for the sash and glass in place. The curtain wall below the sash is figured here at 75 cents per sq. ft. In making the sketches of the exterior wall bay for estimate purposes, no care has been exercised to select stock sizes of steel wall sash. In actual practice, however, this is usually of prime importance. The cost of the extra floor space occupied by the larger wall column has not been considered here, as its influence on these particular columns would be negligible.

Footings.

In the design of concrete footings it often happens that it is difficult to decide offhand whether a plain or reinforced concrete footing should be used. A design of each type of footing should be made and the comparative costs calculated. The engineer knowing the kind of soil these footings will rest upon should price the excavation required at a proper figure. This is a very important part of the footing cost, in fact, many times the most vital part of the estimate for foundation work. In the absence of any more reliable information, the unit costs of excavation per cubic yard (not over 5 ft. deep) may be assumed as follows:

Loam or other easy excavation	$0.75 cu. yd.
Gravelly earth containing small stones	$1.00– 1.50 cu. yd.
Frozen earth	2.25– 2.50 cu. yd.

Rock or ledge excavation	$3.50– 4.00 cu. yd.
Backfill	.30– .50 cu. yd.
Sheeting around excavated holes for footings	.10 sq. ft.

For excavation work over 5 ft. deep and down to 10 ft. deep, the unit cost on the yardage below the 5-ft. depth should be increased approximately 50 per cent. An example is given below with comparative costs for the two types of footings, reinforced and plain, shown in Fig. 3 and Fig. 4, respectively.

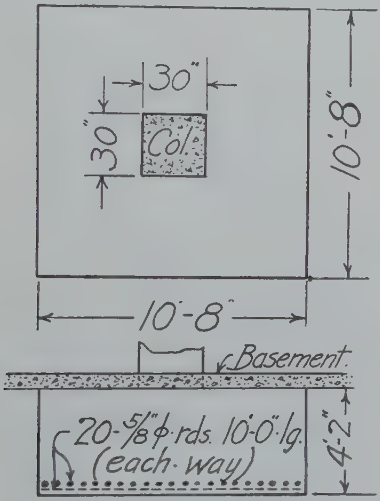


FIG. 3. FOOTING. SCHEME (a).

The excavation is assumed as costing $1 per cu. yd. to remove, and the excavated holes are sheeted close in order to do away with form work around the large footing block.

Scheme (a) Reinforced type (mix 1 : 2 : 4)	Conc	460 cu. ft. at 34c	$156.40
	Forms (none).		
	Reinforcement	420 lbs. at 5c	21.00
	Excavation	19¼ cu. yds. at $1.00	19.25
	Backfill and level	19¼ cu. yds. at 30c	5.78
	3-in. (close) sheeting	182 sq. ft. at 10c	18.20
	Total		$220.63

Scheme (b) Plain type	Concrete 1 : 2½ : 5	507 cu. ft. at 32c.	$162.24
	Forms (top block)	84 sq. ft. at 15c.	12.60
	Excavation	24 cu. yds. at $1.00	24.00
	Excavation below 5-ft. mark	5½ cu. yds. at $1.50	8.25
	Backfill and level	29½ cu. yds. at 30c.	8.85
	3-in. (close) sheeting	270 sq. ft. at 10c.	27.00
	Total		$242.94

As above shown, the reinforced footing is the most economical to use in this case. However, provided stones or "plums" were obtainable at a small expense, the cost of the plain footing could be considerably reduced. It will be noted in the estimates for these two footings that the excavation for the plain footing is the determining factor in its cost. The materials used in the plain footing cost somewhat less than those used in the reinforced type, but the extra depth of the excavation makes the plain type the more expensive one to use. This extra cost becomes still greater when the footings are placed in wet or frozen

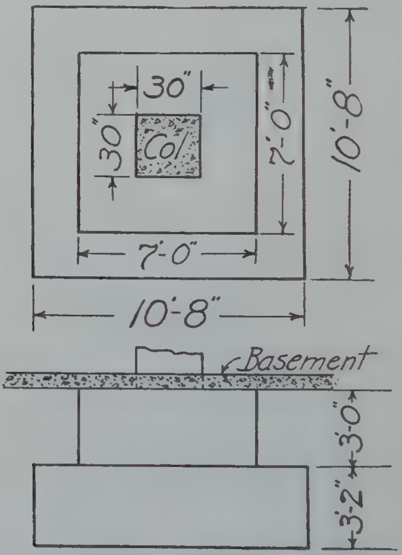


Fig. 4. Footing. Scheme (b).

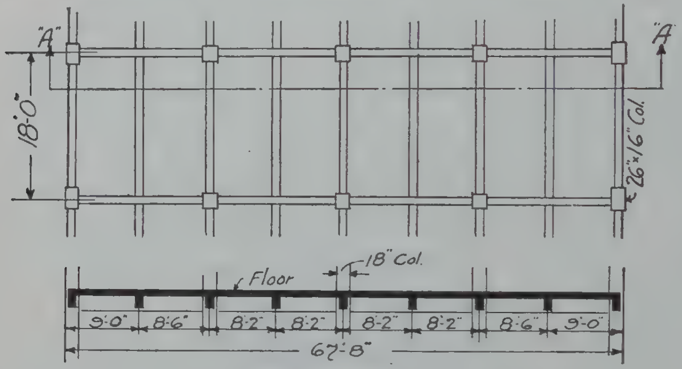
ground, for which excavation costs are considerably more. In case the reinforced type of footing is built with a sloping top, and a wood form is used for this top, the cost would be about the same as though the concrete were poured up to a level with the top of the footing, and the form work omitted, as above estimated. In some operations the top part of a footing is sloped and the concrete poured " dry." This necessitates a change in the batch, slows up operations, and many times does not work out economically. For estimating comparative costs of footings it is not a safe procedure to assume that the top part of the footing will be poured " dry " in order to do away with forms on the slope. Either estimate a form for this sloping surface or figure on the concrete as being poured up to a level with the top of the footing.

Beam and Girder Floors.

It has been previously stated that, in the design of the beam and girder type floor, the omission or addition of one intermediate beam per bay may influence the cost materially. Although this problem is usually handled economically by engineers designing concrete buildings which have usual floor loadings and column spacings, it sometimes happens that when unusual floor loadings and column spacings are required, it is necessary for the engineer to determine a layout which will show the most economy. In a proposition of this kind it is first necessary to make the design which looks most likely to be the economical one. Then two more designs should be made, one having one more intermediate beam and the other having one less intermediate beam. Sometimes the girders should be run in other ways and designs made on layouts entirely dissimilar. Cost comparisons made of these designs will show conclusively which system should be adopted.

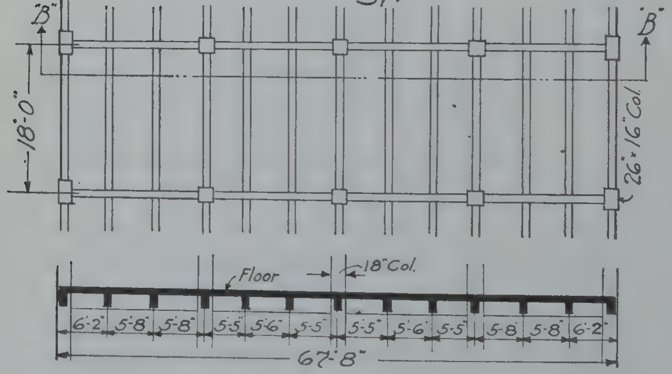
For the purpose of illustrating the methods of estimating beam and girder floors with a view to economy, the two schemes shown in Fig. 5 and Fig. 6, designed for the same column spacings and live loads, are estimated here in a comparative way. Only these two layouts are compared here, but other layouts should be estimated in a similar manner, bearing in mind that the more beams and girders in the floor the more expensive the form work becomes.

In scaling the quantities for the comparative estimates of these two designs, it will be necessary to include all the concrete forms and steel reinforcement in one 18-ft. bay for the full width of the building, which is about 67 ft. 6 ins. In Fig. 5 the quantities will include the slab over one complete bay, 7 intermediate beams, 2 wall beams, and 4 girders. In Fig. 6, the corresponding quantities will include the slab over one complete



Cross Section A-A.
Fig. 5. Beam and Girder Floor (Scheme 1).

3½



Cross Section A-A.
Fig. 6. Beam and Girder Floor (Scheme 2).

bay, 11 intermediate beams, 2 wall beams and 4 girders. Below, under the head of "Estimate, Fig. 5," and "Estimate, Fig. 6," will be found these respective quantities to which unit prices have been fixed (a list of which will be found in Part I), and the total comparative cost of one bay for each scheme estimated.

Estimate, Fig. 5.	
Concrete, 825 cu. ft. at 34c..	$280.50
Forms, 1 860 sq. ft. at 13c...	241.80
Reinfct., 7 300 lbs. at 5c....	365.00
Total..................	$887.30
(Unit cost, 73 cents sq. ft. of floor)	

Estimate, Fig. 6.	
Concrete, 700 cu. ft. at 34c..	$238.00
Forms, 2 000 sq. ft. at 14c..	280.00
Reinfct., 6 300 lbs. at 5c....	315.00
Total.................	$833.00
(Unit cost, 68½ cents sq. ft. of floor)	

In "scaling off" the quantities for comparative estimates of beam and girder type floors, care must be taken to carefully consider the laps in the reinforcement. All steel reinforcement actually occurring in the slab and beams should be estimated. In taking off the quantities, also, it will be found most convenient to first get the quantity of concrete, then the square feet of forms, and lastly the pounds of reinforcement. The order of scaling for the form work and reinforcement should be the same as that followed in getting the quantity of concrete, that is, if beams follow slabs in the concrete scaling, beam steel should follow slab steel in the reinforcement scaling. This method will eliminate to a large extent the liability of error, and also lessen the work of scaling dimensions since the form areas may be taken directly from the scaled dimensions of the concrete work.

The slight changes in column and footing design which might actually occur in two buildings designed with floors like those above estimated, have not been considered here, as the details of column and footing costs are treated elsewhere. However, in buildings several stories in height, this phase of the design should be carefully considered in conjunction with the cost of floor designs when the cost comparisons are made. Even though the spacing of columns remains the same for all schemes considered, the different dead loads may influence the cost of the columns and footings considerably, and the different girder depths may make it possible to vary the over-all height of the columns in order to get the same clear head room.

Flat Slab Floors.

Flat slab floor construction is fast replacing the beam and girder type of floor, and, generally speaking, has advantages in appearance and economy. However, there will be places where the beam and girder system will show a lower cost. Where panels between columns are square or nearly so, the flat slab usually works to advantage. When columns are spaced unequally or irregularly, it is often more economical to resort to the beam and girder type of floor. If the column spacings may be laid out with economy in view, the square bay and the flat slab will generally be selected. However, this selection should not always be made without a proper check by comparative cost estimates. Assuming, for instance, that a concrete storage building is required, the width of which may be anywhere from 55 to 65 ft. and sufficient in length to give a certain specified area of floor space. The design is to be a flat slab system, and the building is to be built as economically as possible. The engineer will usually make a design for a flat slab system with the columns spaced at distances he believes will show economical results. He should now make two more flat slab designs with the column spacings one foot more and one foot less respectively. Comparative costs made on these three designs will show him the economical standing of the various spacings for the specified live load, and if it does not show him definitely which spacing to use it will give him the hint as to which extreme of column spacings he must still continue to design. It will be necessary to make typical cross-section designs showing the column spacings considered and then calculate the comparative costs of each design for a length of building equal to one bay. It is a simple matter to calculate the number of bays necessary for each type of cross-section to deliver the required amount of building floor space. This being done and the cost of one bay of each type of building being already calculated, the total approximate cost of each type of building is easily found. Adding to these respective estimates the cost of closing in the two extreme ends of the building, the engineer has a very good idea of the comparative costs of the designs he has made.

Special Problems.

The principal elements going to make up the cost of a concrete building have been briefly touched upon, with a few illustrations of the methods of making cost comparisons. It is believed the designer will now be able to cope with special problems in a smaller manner, always trying to make actual cost comparisons bear out his decisions whenever it is possible to do so.

The use of rods $\frac{11}{16}$, $\frac{13}{16}$ and $\frac{15}{16}$ in. in diameter should be discouraged, as it is difficult to obtain these sizes. When these unusual sizes appear on the plans, the party estimating the job is likely to protect himself by estimating the reinforcement at an increased cost.

Care should be taken to so design the roof beams that the width will be the same as those in the floor below. By doing this it makes it possible to use the same forms for the roof as were used for the floors, the only change necessary being made on the beam bottoms, which will be raised somewhat to form a beam of less depth.

Effect of Local Conditions on Cost.

The locality of the job in hand plays an important part in the design and cost of the work. Cost comparisons should not be made without regard to this special consideration. Low-priced gravel may take the place of sand and crushed stone. Cement may be unusually cheap owing to very low freight rates. Sand may be procured from a sand bank nearby or possibly from the footing excavation. Crushed stone may be had from a crushing plant close to the site of the job or it may be excessively high in cost. Reinforcement costs may be extremely high on account of transportation. Any one or all of these conditions would influence all concrete units. These local conditions and the prices should be studied by the engineer before starting his design. If he does not do so his cost comparisons may not, after all, lead to the correct conclusions.

It was found, in making comparative estimates of two systems of floor construction, that when the quantities were priced at the rates prevailing in Buffalo the costs of the two designs were about the same. When New York City prices were applied to the same designs a saving of about 8 per cent. of the cost was shown in favor of the design calling for the least concrete and the most reinforcement.

Fluctuation of Unit Costs.

Unit costs of labor and materials for all classes of building construction are constantly changing, and it is hardly to be expected that one whose business is not entirely estimating be kept well informed of the many fluctuations. However, it has been shown in this article that the designer does have to use absolutely accurate unit costs in order to determine by comparative estimates the relative economic standing of his designs. A review of the market conditions from time to time in a general way will give him enough information to revise his unit costs in order that his comparisons may show more accurately the true status of his work. The prices tabulated and used throughout this paper, as before mentioned, are much higher than the prices of two or three years ago. It is quite possible that two years hence they may undergo another change, equally great, and the engineer must look out for this and act accordingly. Five years ago the ratio of cost of concrete, forms, and steel in a building was roughly 2 : 2 : 1. To-day it is about 2 : 1 : 1 — that is to say, five years ago the total cost of the concrete about equaled the cost of the forms, and the reinforcement equaled about one half of the cost of either. To-day the cost of the concrete in a building is slightly less than twice the cost of the forms and the reinforcement is about equal to the forms. It is quite probable that five years from now the ratio may be again changed.

Conclusion.

In this paper many designs might have been made and the comparative cost of each design calculated. Building layouts might have been discussed at length with a view to economy of construction. Economical column spacings for flat slab designs for various live loads could have been worked out. However, with the engineer governed largely by specific conditions, building laws, fiber stresses, etc., it would be difficult indeed to cover the subject, even in a general way, in a paper many times the size of this one. Therefore, it was thought best to give most of the space to methods of estimating the comparative costs of the principal members which go to make up a concrete building, and not deal specifically with the layout of the building. Again, mention is made of the fact that the designs and quantities used here to illustrate the methods of comparative cost estimating are in no way to be viewed from an engineering standpoint. These examples are intended to be of value only in so far as they serve for illustrative purposes, and must not be considered as solutions to engineering problems. It is not within the scope of this paper to lay down rules for concrete design, but rather define and illustrate principles by which the accepted rules may be economically applied. If the engineer has in hand the application of these principles he can solve the question of economy in his layout for himself.

In writing this paper, it is not intended to try to make building estimators of all designers of concrete buildings. It is, however, hoped that it will arouse the interest of the designer to a keener desire to know the cost of his designs, and to promote the practice of comparative cost estimating among designing engineers. Such practice, if conscientiously followed, will be extremely helpful in enabling the designer to choose wisely, and at the same time imbue him with a new confidence that his work really contains the most economical methods to achieve his purposes. He will get a new perspective of his work and develop to a greater degree the capacity for thinking in dollars and cents as well as in stresses and strains. His work will become more interesting and his services of more value. It was with this in view that this paper was conceived, and the effort will be well worth while if this purpose has, even in a small way, been accomplished.

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PAPERS AND DISCUSSIONS

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SEWER PIPE JOINTS.

By J. Leslie Woodfall, Edwin H. Rogers, Henry A. Varney, Lewis M. Hastings, Bertram Brewer, Frank A. Marston and Geo. A. Carpenter.

(Topical Discussion presented before the Sanitary Section, January 2, 1918.)

J. Leslie Woodfall.* — The question of making satisfactory joints in sewer pipe is one which has given engineers considerable trouble, and one which has been a subject of experiment for a great many years.

This subject may be divided under two headings: first, the form of the pipe or joint; and, second, the material to be used in making the joint.

Cement pipe is manufactured with two forms for the joint. In the first, the ends of the pipe are beveled for a short distance, so that the end of one pipe can be forced or placed in the end of the other. The second is the regular bell and spigot pipe.

Vitrified pipe is also made in two forms, viz., ring pipe and bell and spigot pipe.

In the early nineties dissatisfaction among engineers on account of the small space allowed for making the joint resulted in the manufacture of the so-called deep and wide socket pipe. I believe this pipe was first manufactured by the Portland Stoneware Company, from drawings furnished them by M. M. Tidd, civil engineer, of Boston.

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* Civil and Sanitary Engineer, 15 Court Square, Boston, Mass.

This form of bell was soon made by all of the manufacturers, but for reasons of cost a compromise bell was adopted which is now manufactured under the name of Standard Pipe.

During the last few years some of the manufacturers have adopted the making of the deep and wide socket pipe exclusively, and the tendency appears to be towards this size of bell.

Method of Making the Joint.

Joints in sewer pipe, until recent years, have been made mostly with cement. I have been informed that in England well-puddled clay was used to a considerable extent; also the so-called Stanford joint. This latter joint, I believe, was patented and was never extensively used in this country. It was made by filling the inside of the bell with a hot mixture similar to asphalt. The outside of the spigot was then chipped so as to allow it to be covered for a short distance with this same mixture. Molds, made so as to give a beveled surface, were used for pouring the material, and the pipes were forced together, thus making a tight joint. I understand some pipe was manufactured with the spigot end made so as to avoid the chipping.

Cement Mortar Joints.

Different methods of making cement joints are: first, by the use of cement mortar alone; second, by calking a gasket, either dry or soaked in liquid cement, into the bell and then filling the bell with cement; third, by placing the cement in the joint and then calking the gasket in, thus forcing the cement into the bell; and fourth, by the use of cement alone, forcing it thoroughly into the joint with a calking iron and covering the joint with cheesecloth for the purpose of holding the cement in place. In this latter joint small wooden blocks are imbedded in the cement of the bell for the purpose of centering the pipe.

An additional precaution to make the joints tight was used at Malden. This consisted in the use of a small wooden box having the sides cut to the radius of the outside of the pipe, which was placed at the joint and filled with cement mortar up to the middle of the sewer pipe. I used this method a number of years ago, but it did not prove entirely satisfactory.

Poured Joints.

Under this head may be included all of the methods of pouring the joints with hot mixtures. These mixtures are of two distinct classes, viz., that known variously as G–K, Jointite, etc., and that composed of sulphur and sand.

For making any of these joints, deep and wide socket pipe should be used. A gasket is first calked into the bell in a thorough manner, to prevent the material from running into the pipe. A gasket is then clamped around the pipe and the hot material poured in the same manner as in making water pipe joints.

Water must be kept out of the bell while the sulphur and sand joint is being poured. It is claimed that with G–K, or Jointite, this is not necessary, but from such information as I have obtained I judge it is difficult to make a good joint under water. The sulphur and sand joint becomes hard at once, but it is so rigid that the pipe will break if any settlement takes place. The G–K or Jointite compounds do not harden so quickly and have enough elasticity to take care of any slight settlement of the pipe.

In my experience covering thirty years, I have seen three small cases of broken sewer pipe. In one case the joint was made with cement while in the other cases sulphur and sand was used.

Careful levels indicated that the breaks were not caused by a settlement of the pipe.

Among the reasons for building sewers as nearly water-tight as possible are the following:

First, to avoid increasing the size of the sewers to provide for an extreme leakage; second, to prevent the pumping of an unnecessary amount of ground water; third, to prevent the treatment of an increased amount of sewage caused by the leakage of ground water into the sewers; and fourth, to prevent the entrance of tree roots in the sewers through imperfectly made joints.

In order to give an idea as to the relative merits of the different methods of making joints in sewer pipes, as herein described, I will give a record of the leakage in four towns in which we measured the leakage immediately after we had built the sewers.

Easthampton, Mass., in 1893.

The joints were first calked with oakum which had been soaked in liquid cement and then filled with cement mortar. The leakage in about 1¼ miles was at the rate of 55 000 gals. per mile per 24 hrs.

Andover, Mass., in 1898.

The joints were made with cement mortar, which was first placed in the bottom of the bell of the pipe. Two small wooden blocks were then placed in the cement for the purpose of centering; the spigot of the next pipe placed in position, and the remainder of the joint filled with cement mortar calked with a calking iron, and the whole surrounded with cheesecloth. The leakage in 5.48 miles was at the rate of 5 912 gals. per mile per 24 hrs.

Amesbury, Mass., in 1912.

The joints were made with sulphur and sand. The leakage in 3½ miles was at the rate of 9 700 gals. per mile per 24 hrs.

Lexington, Mass., in 1915–1916.

The joints in the vitrified sewer pipe were made with sulphur and sand, and in the iron pipe with lead. Measurements were made at two points: first, at the connection of the outlet sewer with the Metropolitan sewer, and second, at the upper end of the outlet sewer.

The outlet sewer is a little over 2.6 miles in length, of which a little over one half mile is vitrified pipe and the remainder is iron pipe. The length of sewers above the upper end of the outlet sewer is a little over 3.9 miles, and the joints were made with sulphur and sand. The leakage into the entire system of 6.56 miles as measured at the Metropolitan sewer was at the rate of 674 gals. per mile per 24 hrs., and for the 3.9 miles of the system above the upper end of the outlet sewer at the rate of 71 gals. per mile per 24 hrs.

Taking everything into consideration, my conclusions are that a nearer water-tight joint can be secured by pouring.

Edwin H. Rogers.* — The city of Newton, Mass., has a separate sewerage system, and for the past eleven and one-half years a sulphur and sand compound has been used exclusively as a jointing material for its vitrified pipe, sanitary sewers, and house connections, and for a limited amount of surface drains.

From June, 1906, to January, 1918, 28½ miles of vitrified pipe sanitary sewers and 31½ miles of vitrified pipe house connections have been laid with this compound of sulphur and sand. The total mileage of vitrified pipe sanitary sewers is now 118 miles, thus making 24 per cent. the proportion with the sulphur compound; and the total mileage of house connections is now 98½ miles, thus making 32 per cent. of the house connections laid with this material.

The size of the pipe sewers so jointed varies from 8 ins. to 20 ins., but 89 per cent. of these sewers are 8-in. laterals. The house connections are 5 ins. with a few cases of 6 ins.

The method of making the joints in the pipes is similar to the pouring of lead joints in water mains. After fitting any two pipes closely together, the joint is calked with jute oakum, usually about ½ in. to 1 in. in depth, but only sufficient to prevent the jointing material from running into the interior of the pipe. A pipe jointer is then placed around the outside of the spigot end of one pipe close against the bell of the adjacent pipe, leaving a triangular opening on top of the pipe through which the joint is poured full with the moulton mixture of sulphur and sand. A ladle large enough to hold sufficient material to pour the joint completely full at one operation should be used, and sufficient time given for the sulphur and sand compound to harden before removing the pipe jointer. After removing the jointer, the exposed surface of the sulphur and sand mixture is painted with hot roofing pitch to close up any possible voids or slight temperature cracks. It may be questioned if this practice is an absolute necessity, but the cost per joint is but slight, only about half a cent per joint, and is an added precaution for water tightness. The Tee branches provided for future house connections are closed with a stopper held in place by roofing pitch, so as to be readily removed when necessary to make a connection with a house connection.

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* City Engineer, Newton, Mass.

The sulphur and sand are mixed in equal parts by measure and melted together in an iron pot held in an iron frame and suspended over a fire of waste wood. Gasoline furnaces were previously used, but owing to the increased cost of gasoline the mixture is now heated by waste wood which is almost always to be found on a piece of sewer work. When gasoline was used for fuel for melting it required about .07 of a gallon of gasoline per joint.

The correct temperature to which the compound should be heated for use averages 260° F. The use of a thermometer is unnecessary after the workmen become accustomed to handling the mixture, as the correct temperature is easily ascertained by inspection. If it is too cold, it will not flow properly, and if too hot the tendency is to foam in the kettle. The use of the compound does not involve any waste material, for that which is left unused in the kettle is melted the next time it is wanted and fresh material added, together with any fragments left from defective joints from leakage around the jointer in pouring the joints.

The sulphur is powdered sulphur of commercial quality, bought by the barrel. The sand is a very fine quicksand, which is obtained from a pit on the city of Newton water-works reservation in the town of Needham. A great deal of the success of this type of joint depends on the fineness of the sand. Tests of the sand in use indicate that 90 per cent. will pass a sieve having 100 meshes per linear inch and 50 per cent. will pass a sieve having 200 meshes per linear inch. The pitch is ordinary roofing pitch. The jute is the usual type of tarred jute oakum. The pipe used is invariably deep and wide socket, as the annular space between the bell and spigot in standard pipe is considered too narrow for the best work.

The cost of sulphur varies from 2½ cents per pound in 1907, to 3 cents per pound in 1910, and 4.35 cents per pound in 1917. The sand is charged to each piece of work at the rate of $1 per barrel of 250 pounds or 0.4 cents per pound. The cost of the jute varies from 5½ cents per pound in 1918 to 8½ cents and 10 cents per pound in 1917. The cost of the pitch varies from 1 cent per pound in 1908 to 1.3 cent per pound in 1917.

The quantities of material per joint required for 8-in. pipe are about as follows: sulphur, 1½ lbs., sand, 1½ lbs.; jute ½ lb.; pitch, 0.4 lb. For 5-in. pipe the quantity of sulphur is about nine-tenths pound, and other materials in proportion. On the basis of present-day prices, the cost of materials for an 8-in. joint would be from 11 cents to 12 cents, but until recently the cost has been considerably less.

In 1907 a careful comparison was made of the cost of laying an 8-in. pipe sewer of 38 cement joints with an 8-in. sewer having 31 sulphur and sand joints. This test, which included the labor and materials for laying the pipe in both instances, showed a cost of 26.5 cents per joint and 23.8 cents respectively, or that the sulphur and sand joint cost 90 per cent. of the cement joint.

The advantages of the sulphur and sand joint appear to be many, and the following may be taken as the principal reasons for its use. When properly made, it is practically proof against leakage or infiltration and is entirely resistant to tree roots, while at the same time is not complicated and is readily executed. There appears to be no material difference between the cost of sulphur and sand joints and cement joints, and whatever difference there may be is a small percentage of the cost of the sewers. In laying pipe up to 8 in. in diameter inclusive, three lengths of 3-ft. pipe can usually be jointed on the bank, where a perfect joint can be made with great ease and then lowered into the trench, and, in the case of 10-in. or 12-in. pipe, two 3-ft. lengths can be so joined, whereas with cement joints the practice is to make every joint in the ditch. In other words, with the sulphur and sand joints in the smaller sizes of pipe, only 33 per cent., and in the medium sizes 50 per cent., are difficult of inspection, as against 100 per cent. with cement joints. It requires excellent workmanship and vigilant inspection to make sure that cement joints are properly made, particularly at the invert of the pipe, whereas the sulphur compound tends to run around the bottom of the pipe and make the joint most secure at this point. No difficulty is experienced in cold weather by the use of the compound. In extreme weather and when the pipe is cold, it is easily heated by putting a string of tarred jute around the pipe at the joint and setting it on fire, thus heating the pipe sufficiently so that there is no difficulty in running the joint. After the joint is made, freezing weather will not hurt the sulphur compound, whereas cement joints should be protected from frost until the mortar is set. The time of setting of the sulphur compound is inconsiderable, for it is hard as soon as it is reasonably cool, whereas cement joints require a considerable period to harden.

Sulphur and sand joints are not flexible, but this is true of cement joints, and where there is a good foundation, nonflexibility in the sewer is no detriment in its construction. The sewer is usually placed at the lowest level of any of the structures in a street, and when it is laid in any material that provides a good foundation and is not susceptibile to settlement, there appears to be no disadvantages in a rigid joint, and in fact the rigid joint will frequently assist in maintaining the grade and alignment of the sewer.

The soil in Newton through which the sewers are laid is mostly hard pan, gravel, sand or ledge, there being but little subsoil of peat or of filling. The sewers are under constant inspection, and breakages are of very infrequent occurrence, there having been but two or three breaks in the 60 miles of pipe jointed with the sulphur compound since its use was adopted from settlement of the foundation of a sewer or house connection.

Trouble is frequently encountered from tree roots on nearly all of our sewers which are laid with cement joints in which there are trees along the side of the street, and the same is true of the older house connections laid with cement joints with trees in the near proximity. We have had absolutely no trouble from the growth of tree roots in sewers or house connections laid with sulphur and sand joints.

The sewage in Newton is largely from dwelling-houses, but no difficulty has been experienced with deterioration of joints from sewage from any of the comparatively few mills or factories, the sulphur and sand compound only being affected by chemicals which are most rarely found in the trade wastes from manufacturing establishments and not at all in dwelling-house sewage.

The writer is indebted to Mr. James A. Darling, superintendent of sewer construction of the street department of Newton, for much of the cost data and information as to breakages, etc., in this article.

HENRY A. VARNEY.* — Brookline has tried many different materials for sewer pipe joints, but as yet has found nothing that is entirely satisfactory.

For many years Roslindale cement mortar was used, and no great care taken in forming the joint, which resulted in much trouble from tree roots, and a large amount of leakage in wet ground.

Later on, Portland cement was substituted for the natural cement, and the pipe centered with a jute gasket. But with every precaution we were able to enforce, such as the use of rubber gloves in applying the mortar and deferring the heavy backfilling until the cement had thoroughly set, the results were not at all satisfactory. In one case where there was a large amount of ground water, we constructed wooden boxes to fit the lower half of the pipe and long enough to extend each side of the bell. These were set to the proper grade, then filled with rich mortar, so there could be no question but that each joint was thoroughly bedded and protected. With all these precautions, there was considerable leakage. In another instance we encased the entire pipe in 6 in. of concrete, but with no better results.

We then tried the sulphur and sand joint similar to that used in Newton. By this method we greatly reduced the amount of leakage, but we were apprehensive that such a rigid joint as this material makes from the moment it is poured would result in cracks in the bells or the pipe itself, for it is difficult to bed several lengths of pipe so as to prevent all possibility of movement when the backfilling and puddling is completed.

We next experimented with various bituminous compounds, and in 1909 used a mixture of asphalt and sand in laying a 30-in. sewer. This gave so much better results than anything we had

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* Town Engineer, Brookline, Mass.

TABLE 1.

DATA RELATING TO SEWER PIPE JOINTS.

City or Town.	Material Used.	How Long Used.	Why Is This Material Used.	Work Done by City or Contract.	Other Material U
Boston	Cement mortar	30 yrs.	No better for all purposes	Both	None
Brockton	Portland cement	25 yrs.	Think it the best	City	G-K compou
Brookline	Asphaltic compound	10 yrs.	Gives best results	Contract	Cement, Sulphur and s G-K compou
Cambridge	Cement mortar	28 yrs.	Considered practical	City	Bituminous filler
Concord, N. H.	Cement mortar	25 yrs.	Makes Effective joint	City	Roman cem
Haverhill	Cement mortar	Many yrs.	To prevent entrance ground water and tree roots	City	None
Lawrence	Cement mortar	Always		City	None
Lynn	Cement mortar	40 yrs.	Most convenient	City	None
Malden	Cement mortar	26 yrs.	Considered best	Both	G-K compo
Melrose	Cement and G-K compound	G-K past 2 yrs.	On account of wet trenches and tree roots	City	
New Bedford	Cement mortar	Many yrs.	For convenience and economy	City	G-K compo
Newton	Sulphur and sand	11 yrs.	Permanent water-tight and resistant to roots	Both	Cement mo and bitumin compoun
Pawtucket	Cement mortar	20 yrs.	Most satisfactory	Both	None
Worcester	Cement mortar cloth-wrapped	20 yrs.	Because it has given good results	City	None
Metcalf & Eddy	G-K compound	5 yrs.	A poured joint considered best	Contract	Sulphur and

TABLE 1. — *Continued.*

DATA RELATING TO SEWER PIPE JOINTS.

lave you ad Trouble rom Tree Roots?	Does Present Type Prevent Roots?	Does it Make Water-Tight Joints?	What Material Used in House Connections.	Remarks.
Yes	No	No, except with extreme care	Cement mortar	Experiment under way with special material.
Yes	No	Yes	Portland cement	Iron pipe with lead joints used where roots give trouble.
Yes	Yes	When carefully used	No regulations	House connections laid by private contractors.
Some	Yes, if carefully made	Yes	Cement mortar	
Yes	Yes	Yes, when well made	Cement mortar	
Yes	Yes, if done properly	Yes	Cement mortar	
Yes	No	No		Combined system of drainage.
Yes	No	Nearly	Cement mortar	Iron pipe with lead joint used where tree roots give trouble.
Yes	Yes, if made properly	Yes, if made properly	Cement mortar	
Yes	Yes	Yes	Any	Troubled with tree roots in house connections and some main sewers.
No		No	Cement mortar	
No	Yes	Yes	Sulphur and sand	
ery little	Not entirely	Not entirely	Cement mortar	Quality of work depends upon inspectors.
No	Yes	Fairly	Cement mortar	
No	Yes	Fairly so	G-K compound	

previously tried that we continued its use, and up to the present time have found nothing that is more satisfactory, considering the ease of manipulation, cost, etc. The method of making a joint with this material is similar to that used for lead joints, except that the material does not have to be calked. It also required very little heat to bring the compound to the proper consistency, a small wood fire being all that is necessary. We take the precaution to fill the angle between the bell and the barrel of the adjacent pipe with cement mortar, but do not think this is absolutely necessary, especially in the smaller sizes of pipe.

We have recently inspected some of the first work done with this material and have found the joints in perfect condition, and could see no change in the consistency of the compound itself.

In Table I are tabulated the results of an inquiry as to methods used in other communities.

L. M. HASTINGS.* — In Cambridge, experience has shown that the larger-sized sewer pipes are not adapted to the conditions as to foundation, load, etc., which obtain there, without danger of fracture of the pipe. For some years now, it has been the practice to confine the use of vitrified sewer pipe to sizes of fifteen inches in diameter and under. Diameters larger than fifteen inches are made of concrete, brick, or a combination of the two materials. Sometimes the invert of the sewer is made by casting the same in the trench in prepared forms. This makes an excellent base without joints and is sometimes quite inexpensive in construction, as sand and gravel found in the trench, if suitable, can be used.

One disadvantage of this type is the time required to allow the concrete to set before the forms are removed and the arch placed, thus delaying the trench backfill. In some recent work with a heavy cut, a pre-cast invert was used with very satisfactory results. A section of two sizes of this sewer is shown in Fig. I. The inverts are cast in lengths of two feet, and the arch pieces in lengths of three feet. The end joints are made up by plastering the ends with rich mortar placing a gasket of hemp near the outer edge and squeezing them together by sliding them on the plank mud sills which have been carefully set at the proper sub-grade. All joints are pointed inside and out after the pieces have been set. Very little time is lost in constructing the sewer by this plan, as the trenching work can be carried on almost continuously. The concrete sections are made by the regular sewer men at the yard, so that they cost but little more than the cost of stock and transportation.

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* City Engineer, Cambridge, Mass.

Our practice in making up the joints in 8, 10, 12 and 15 in. pipes, is to use Portland cement mortar and use the fingers and trowel in filling the joint and forming the collar outside. Warren Bros.' bituminous joint compound was used several years ago, but the city men, accustomed to the use of cement, preferred that, and so the superintendent of sewers thought that there was not advantage enough in the Warren Bros.' compound to warrant a change. Such trouble as we have has been caused almost invariably by careless work in making up joints of the main city sewer, or the connecting house drains. It must be remembered that a prolific source of stoppages, roots and leakage in public sewers is broken and defective house connections, which no amount of care or expense in the city construction will eliminate.

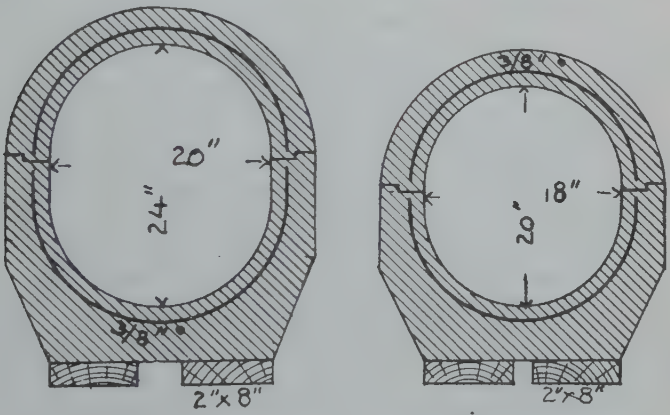

FIG. I. CITY OF CAMBRIDGE. CONCRETE SEWER SECTIONS.

Personally, I believe that the cement joint — unless an expert is employed on the work — is likely to give as good results as any. Its simplicity, ease of handling the material and detecting imperfections, and its common use by masons and other workmen, are strong points in its favor. I believe, however, that the poured grout is the best way in which to use it and get a full joint. With the poured joint, liability of having an imperfect joint on the bottom side of the pipe is reduced to a minimum and must be the result of gross carelessness, as the bottom part should be best part of the joint by this method. The pipes are first lined up and centered, and a strand of oakum lightly driven into the joint, and then the joint is poured. Various devices have been suggested for holding the cement grout in place when poured. A very simple and inexpensive one is a sort of band or collar made of paper fabric about two and one half inches wide, one edge of which is attached to the bell of one pipe and the other edge is attached to the body of the next pipe, by cords passing around the pipe and firmly binding the collar to it. The grout is then poured into the joint space through a hole in the collar until it is entirely full. The collar can be left in place, as the expense of the collar is very small.

Bertram Brewer.* — The Waltham sewer system consists uniformly of sanitary sewers. It is 46.5 miles in extent, with 44.7 miles of vitrified clay pipe. This pipe is of all sizes up to twenty-four inches in diameter. Seventy per cent. of the sewers was laid by contract before Portland cement was known, and natural cement mortar was used for jointing in the proportion of one part of cement to two of sand. A jute gasket was calked into the joint before applying the mortar. Underdrains were constructed to a great extent in wet trenches, and care was exercised to secure water-tight sewers. Considering the hurried manner in which the work was prosecuted and the lack of skill of both the pipe layers and inspectors, the results were very good. Measurements of the Waltham sewerage, taken by the Metropolitan Sewerage Board, show that Waltham sewers are about as free from ground water as those of any other municipality in the district. As soon as the original contract was completed, the city laid many of the connections by day work. These also were hurriedly laid and not enough care was taken in the jointing.

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* City Engineer and Superintendent of Water Works and Sewers, Waltham, Mass.

Two difficulties with this early construction soon developed. First, the jute gasket has proved more of a nuisance than a help, because in a great many cases it was not properly calked into place. After the contract was completed there was hardly a section of sewer which did not show on examination either a string or a loop of jute protruding into it. The second difficulty had to do with tree roots. Probably no one could tell a bigger story of the length and size of tree roots taken from the sewers than the Waltham authorities.

Most accounts of the improvements in sewer jointing begin with the introduction of Portland cement. For general use, with the ordinary bell and socket pipe and in dry work, nothing better than Portland cement mortar has been discovered. A rich mortar joint, one of cement to one of sand, uniformly pressed into the space between bell and socket and wound with cloth, has been found to keep out tree roots, over and over again. It accommodates itself to the slight movement which every pipe experiences before backfilling is complete. Moreover, if given a chance to set up without being seriously disturbed, such a joint is nearly water-tight.

The discovery of the use of the cloth wrapping is one of the greatest improvements in sewer jointing yet introduced. It gives the skilled pipe layer an excellent opportunity to pull and push and smooth the mortar into place and protects the mortar during backfilling.

When used with a large follower, large enough to fully clean the inside of the pipe, the gasket is not necessary, is not as permanent as the cement, and has been abandoned.

For wet work both the sulphur-sand and the asphaltic composition joint have been thoroughly tried. The asphaltic joint has been adopted.

The first sulphur-sand joints were used in 1907, in a connection where a water and drain pipe were laid in the same trench. The water pipe was laid after the sewer, and, as a result of the jarring the sewer received, several pipes were broken, all of them on the line back of the bell. This joint was, however, used in several wet trenches later in that season. There is no difficulty in securing a sand in Waltham fine enough for the sulphur joint, and the men soon learned to heat the mixture properly. After that year, however, it was abandoned. The experience cited indicated that the joint was too rigid. The writer has never yet seen a sewer where there was not some movement of the pipes after they were laid. It might be only very slight and, with care, it need be only very slight, but in the case mentioned, where there was no appreciable change and the pipe was subjected to very little stress, failure resulted. Further experience goes to show that the decision to abandon the use of the sulphur-sand joint was a sound one. In 1917 a 300-ft. line of 5-in. pipe, laid ten years before, where the joints were of the type now under consideration, was taken up and relaid at a lower level. When excavated, this sewer to all appearances was at a true grade and perfectly sound, but when jarred out of line, over a third of the pipes were found to be completely fractured at the back of the bell. The annular cracks were so fine that they could not be seen until the sewer was moved.

The asphaltic compositions since 1907 have been invariably used in wet places. Thus far no failures have been discovered. The Warren Bros.' pipe jointing compound has usually been employed. A jute gasket is calked into place and the compound poured into the joint in the usual manner. In shallow trenches every third joint, and in deep trenches every other joint, is made up in the trench; the rest are poured on the bank. With the asphaltic, as well as with the sulphur-sand, joints only deep and wide socket pipe was used. Both the inside of the bell and the end of the spigot should be scored by the manufacturer, else the pipes are liable to pull apart. Care must be taken to see that the compound does not break through the gasket and protrude into the sewer.

The asphaltic joint has been used in Waltham on domestic sewers only, and the danger of hot water melting the compound has never arisen. Its great advantage is that it has considerable flexibility and can be used in a wet trench and without an underdrain, unless there is more ground water than can be taken care of with a trench pump operated with a gasoline engine. A covering of Portland cement has sometimes been added to keep the compound in place, in case it should later be subjected to unusual heat; but, if the cement is to be made at all effective, this necessitates the introduction of expensive unwatering operations, which are not required with the composition alone. The cement covering was, therefore, used on the earlier jobs only.

A few years ago the department laid about 120 ft. of 10-in. pipe in a shallow, wet trench alongside of a brook. The ends were plugged and the sewer was left over night without backfilling. During the night the water rose considerably, and in the morning the whole 120 ft. of sewer was afloat. This experience increased our faith in the asphaltic jointing compound. When trying it out at the sewer yard, four years ago, two pipes joined together at that time were left there for observation. They have been exposed to all kinds of weather, kicked about and pretty well abused. The joint in these pipes is perfect to-day, and they are in as good alignment as they were the day it was poured.

Of course the human element in the art of joint making is the most important one, after all. The writer would prefer a skilled and conscientious workman above everything else. If, in addition, one can be found who will also make an intelligent use of the latest discoveries in the art, the engineer is indeed fortunate. Engineers should also bear in mind that many vitrified clay pipes are somewhat porous thoughout, and it is, therefore, very doubtful whether all the leakage in the sewer comes altogether from the joints.

In conclusion we would suggest that for deep trenching we want, in common with the contractors, a kind of joint which will allow immediate backfilling over it. The saving in cost, effected by throwing the bottom layer of earth ahead of the pipe just laid, on top of it as backfilling, is of great importance to those who pay the bills.

DAVID A. HARTWELL.* — During the last seven years in Fitchburg sewer pipe joints in sanitary sewers have been of two kinds, depending largely upon the trench conditions. Where the trench was comparatively dry with no probability that the water plane would for any length of time, if ever, be above the pipe, a cement joint was used. These joints consisted of a ring of jute calked in to assure a uniform annular space. The jute was soaked in a thin mixture of cement and water. The balance of the joint was filled with a one-to-one mixture of cement and sand pressed in by the hand and trowel and the outside smoothed off on a bevel. Portland cement was always used, and care taken to assure as tight a joint as possible, not on account of ground water but to avoid trouble from roots.

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* Formerly Chief Engineer, Sewage Disposal Commission, Fitchburg, Mass.

Where the water plane was normally above the pipe, and where there was water in the trench, a poured joint of what is commercially known as G-K compound was used almost wholly. Other similar material was used to some extent, but G-K seemed to be more satisfactory. A round commercial gasket was used. The joint was first calked with dry jute, using no more than enough to assure a uniform annular space and to prevent the jointing material from running into the pipe. Joints were poured when the water stood as high as 6 to 8 in. above the invert, and no difficulty was found in making the joints tight enough to prevent any objectionable leakage, The G-K was melted in a gasoline kettle owing to the better control of the heat than when wood is used. It was found advisable to keep the same workman on the kettle as there was less liability of injury to the material when a man has had some practical experience.

All sewer pipe used in recent years has been in 3-ft. lengths when obtainable, and also has had deep and wide sockets. Standard pipe is more economical than deep and wide socket pipe, as it takes less material to fill the joint. But with allowable variation in the diameter of the pipe the annular space with standard pipe was so small that it was decided to use deep and wide socket. It was considered that the cost of the additional amount of jute and compound or cement was more than offset by the better joint secured.

In the construction of drains or storm sewers, cement joints only were used, as with these sewers it was not expected that there would be any trouble from roots, and the elimination of all ground-water leakage was not considered important.

The cost of joints made with G-K compound was found to be about one third more than cement joints, and owing to this additional cost it was decided to use this material only where there was water in the trench.

Frank R. A. Marston.*— Prior to 1907, Metcalf and Eddy specified cement mortar joints for vitrified pipe in separate sewers as well as storm drains, but since that year some form of poured joint has been generally used in their practice, where it was essential to keep out ground water.

The cement mortar joints are now specified as follows:

> The joints shall be as nearly water-tight as possible, and shall be made with a gasket of hemp or jute and cement mortar composed of one part of sand and one part of Portland cement. The gasket shall be soaked in a satisfactory mixture of neat Portland cement and water and then inserted between the bell and spigot and carefully calked into place with suitable calking tools. The gasket shall be in one continuous piece for each joint and of such thickness as will bring the pipe to the required relative position. The remainder of the joint shall be filled with cement mortar applied with the hands, protected with rubber mittens, well pressed and calked into place, after which the joint shall be beveled off with mortar for a distance of two inches from the outer edge of the bell. The joint shall be wrapped in unbleached cotton cloth, securely tied to prevent the mortar from slipping or being otherwise injured. No surplus mortar or other foreign substance shall project into the pipes from the joints, and if necessary, they shall be properly cleaned with a suitable scraper or by other means before the mortar becomes hardened.

It has been found difficult on contract work, to get sufficiently water-tight joints in this manner, although the use of cheesecloth for wrapping the joints was of value in preventing the bottom of the joint from falling off.

A mixture of sulphur and sand — using equal parts by volume of flour of sulphur and very fine sand — was used on several contracts. Unless the sand is very fine and practically free from clay the resulting joint is apt to shrink on cooling, causing objectionable cracks. Further, the sand, if too coarse, tends to settle out of the mixture, causing trouble in pouring and shrinkage of the joint. Some very successful work, however, has been done with this material. It appears to require more care in heating than some other mixtures. The chief difficulty has been to get a satisfactory mixture, due almost entirely to the size and quality of the sand. On contract work, this is a disadvantage. The joint, also, is absolutely rigid, as is the case with cement mortar.

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* Designing Engineer, with Metcalf & Eddy, 14 Beacon Street, Boston, Mass.

When using sulphur-sand joints, the joint, after being poured and while warm, was coated with hot tar as a further precaution against leakage.

During the last few years, a number of compounds for jointing vitrified pipe have been placed on the market. Since 1913, Metcalf & Eddy have used that known as G-K compound, now made by the Atlas Company, of Lincoln, N. J. This material, said to be made largely of vulcanized linseed oil and clay, resembles vulcanized rubber or coal tar in appearance. It is delivered to the work as a solid, in barrels. It is easily melted by heating in an iron kettle over a fire, preferably using gasoline or kerosene, so that the heat may be controlled.

Specifications for making this form of joint as well as sulphur-sand, are as follows:

> Where plastic joints are specified, the pipe shall be laid as previously specified, and the joints shall be thoroughly calked with a gasket of hemp or jute in one continuous piece, and of such thickness as will bring the pipes to the required relative position. The gaskets shall be calked dry and shall form a water-tight joint. The plastic compound to be used in jointing the pipes shall be that known as —— compound, manufactured by ——, or other plastic jointing material satisfactory to the engineer. The compound shall be heated in a gasoline or other suitable furnace, to a temperature slightly above that at which it will pour rapidly and smoothly; at which it shall be kept until used. After the pipe joint has been calked, the melted compound shall be poured into the joints by the use of a joint runner or gasket, in a similar manner as lead joints are poured. In case the pipe joint is not completely filled, that part of the joint shall be poured again with hot material, to form a complete water-tight joint. Wherever permitted, sections composed of two or three pipes may be jointed at the side of the trench, provided the pipes are set in a suitable wooden cradle to ensure true align-

ment. In lowering sections, so made, into the trench, a piece of timber shall be run through the pipes in order to support their weight and prevent the joints or bells from being broken.

Asphalt has not been used, or any of the bituminous compounds, to any extent, because of the danger of hot water or steam melting out the joint due to the low melting points of most of these materials. With a sufficiently high melting point, this objection would be covered.

Some trouble has been experienced during cold weather with G-K compound, due to its failure to stick to the pipes, especially in the smaller sizes where the inside of the bell is glazed and there are no scorings.

From tests made both in the laboratory and on contract and day labor work, the results obtained with G-K compound have been satisfactory.

The cost of a jointing material and labor will be from 50 per cent. to 100 per cent. more with a poured joint than with cement, judging by average prices received. Part of this excess cost is doubtless due to the unfamiliarity of contractors in general with poured joints for vitrified pipe.

Sheet metal forms and gaskets for pouring cement grout joints have recently been placed on the market by Mr. L. A. Weston, of Adams, Mass. The device is shown in the accompanying cuts, Figs. 2 and 3. The writer understands that the price of the gasket is ten cents for a 10-in. pipe and ten cents for the form, thus making a cost of twenty cents per joint for the form and gasket. The gasket, of course, is left in place, and it would appear probable that the form, also, would be left in place, as a rule. The gasket is made to fit over the spigot end of the pipe, being tightened with a screw driver. The notches in the edge are pliable so that the gasket adjusts itself to the inequalities in the pipe hub. No jute is required.

The form provides for pouring the lower half of the joint, the remainder being filled by hand with cement mortar. The form is held in place by wires.

In order to offset the expense of the form and gasket, a material saving in labor cost must be made in addition to the saving in cost of materials over poured joints using other materials than cement.

It seems to the writer that there is a good deal of merit in Mr. Hastings' suggestion to pour the entire joint with thick cement grout, using a paper or other cheap form which can be left in place and make it unnecessary to keep the trench open more than a few hours at the most.

The writer believes that a poured joint is the most desirable form of joint yet devised where it is essential to prevent the entrance of roots and ground water. Good results have been obtained with a sulphur-sand mixture, with bituminous compounds such as those manufactured by Warren Bros., Boston, the Pacific Flush Tank Company, New York, the Standard Paint Company, Boston, and others; and with G-K compound,

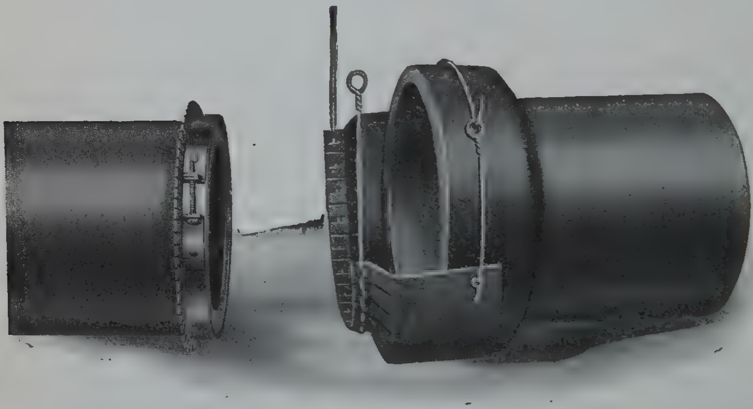

Fig. 2. Weston Gasket and Form.

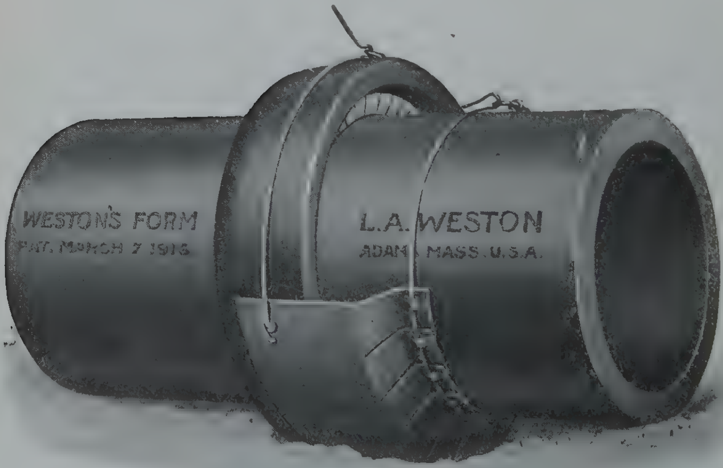

Fig. 3. Weston Gasket and Form in Position for Pouring.

made by the Atlas Company, Lincoln, N. J. On contract work, these commercial compounds may have some advantages from the contractor's viewpoint.

On account of the imperfections in the so-called " standard " socket sewer pipe it is almost necessary to use " deep and wide " socket pipe if poured joints are to be adopted. Otherwise there is liable to be insufficient space for the flow of the jointing material.

GEORGE A. CARPENTER.* — We have had no experience with the poured joint in Pawtucket, for we have adhered to the old-fashioned mortar joint. In recent years we have required the mortar to be placed by hands covered with rubber mittens rather than by the trowel, and we have recently used a strip of cloth about nine inches wide to cover the joint after it is made. This strip of cloth is laid on the ground, partly under the bell of the pipe last laid, and mortar is spread on the cloth and in the bottom of the bell with a trowel. A gasket is then placed around the spigot of the pipe to be laid, and it is inserted in the bell of the other pipe, care being taken not to disturb the mortar spread on the bottom of this bell. The pipe is pushed home, brought to proper line and grade on the bell end and the gasket is calked. The joint is then filled with Portland cement mortar proportioned one to one, especial care being taken to see that this mortar is crowded into the joint on the under side of the pipe. The mortar joint is beveled with a trowel, or by the hand, and then the two ends of the strip of cloth are brought up around the joint and tied together over the top of the bell. This serves as a protection to the green mortar, holding it tightly up against the joint and preventing its disturbance as the backfilling progresses.

After all is said, however, the integrity of the sewer joint depends, in large measure, upon the inspector. If he is not on the job all the time, watching the joints as they are made, the workmen will get careless. The joints will be perfect on the top where they are readily inspected, but on the bottom, where there is the greatest necessity that they should be tight, they are apt to be neglected.

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* City Engineer, Pawtucket, R. I.

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